Employing Knowledge Resources in a New Text Planner Architecture

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Employing Knowledge Resources in a New Text Planner Architecture

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Abstract

We describe in this paper a new text planner that has been designed to address several problems we had encountered in previous systems. Motivating factors include a clearer and more explicit separation of the declarative and procedural knowledge used in a text generation system as well as the identification of the distinct types of knowledge necessary to generate coherent discourse, such as communicative goals, text types, schemas, discourse structure relations, and theme development patterns. This knowledge is encoded as separate resources and integrated under a flexible planning process that draws from appropriate resources whatever knowledge is needed to construct a text. We describe the resources and the planning process and illustrate the ideas with an example.

1 Introduction

When generating a multisentential text, one has to perform several different types of tasks, such as selecting the material to be included, organizing this material into a coherent message, choosing words, and generating grammatical sentences. We describe in this paper a new text planner being built jointly at USC/ISI and GMD-IPSI that performs portions of the generation process. It is based on theoretical studies and experiments in text coherence, e.g., Rhetorical Structure Theory (Mann and Thompson 88), Conjunctive Relations (Martin 92), theories of discourse, e.g., (Grosz and Sidner 86, Polanyi 88),

Authors are listed in alphabetical order.

and text planning, e.g., (Hovy 88, Moore and Paris 89), advancing on those ideas and handling several new aspects of the problem.

This new text planner was designed to address several problems that we had encountered in our own systems and had observed in other, similar enterprises. An important motivation was a clearer separation of declarative and procedural knowledge in a generation system, as well as the identification of the distinct types of knowledge necessary to generate a text (for e.g., Paris and Maier 91). We had noticed in our current systems that, as the planners' plan libraries grew, the same information (e.g., requirements of use and other preconditions) had to be represented several times, and it became harder to add new plans and to modify existing plans because of their interrelationships. Furthermore, existing planning systems often mix information regarding the planning process and information necessary for linguistic realization in one single plan operator. Finally, some of the linguistic knowledge necessary to plan a text is sometimes encoded in the planner itself, rendering the process more opaque. To address these problems, we attempt to make as clear as possible the distinction between procedural and declarative information, and to identify precisely and separate out the different types of knowledge required for creating a discourse structure.

We first present the knowledge sources that we have so far identified. The planning process is then described, followed by an example of text planning.

2 Knowledge Resources Required for a Text Planner

Our text planner embodies an attempt to isolate and use some of the major knowledge resources required to plan multisentential text.[2] In this section, we present the major knowledge resources that we have so far identified, namely: *text types, communicative goals, schemas, discourse structure relations*, and, finally, a resource to handle *theme development and focus shift*.

In some cases, the knowledge resources embody information about the order of some planning operations. Such resources we have implemented as systemic networks; they are the discourse relations and theme patterns. In other cases, the knowledge resources provide information which the planner uses to make decisions. Such resources we have implemented as property-inheritance networks; they are the text types, communicative goals, and schemas. Both types of representation are declarative, enable us to capture inherent commonalities within the resource, and promote notational clarity and simplicity of processing.

[2] We consider discourse to be a structured collection of clauses. This structure is expressed by the nesting of segments of the discourse; a discourse can thus be represented as a tree structure, in which each node of the tree governs the segment (subtree) beneath it. At the top level, the discourse is governed by a single root node; at the leaves, the basic segments are single grammatical clauses. Each discourse segment has an associated purpose, which, following Grosz and Sidner (1986), we call the Discourse Segment Purpose, i.e., a communicative goal. Each adjacent pair of such purposes is related in the discourse structure by one or more discourse structure relations, as described in Section 2.4.

Each node in either type of network may contain one or more *realization operators* which indicate the effects of choosing the node, such as making additions to the discourse structure, choosing subsequent nodes to visit, setting requirements upon subsequent grammatical realization, etc. Knowledge resources co-constrain each other via these realization operators. In Section 3, we describe how the property-inheritance networks are used and the systemic networks are traversed during the planning process, and how a text structure is built during the traversal.

This planner is far from complete. Motivations for various choices have not been fully identified and several important text planning functions, such as noun phrase planning, lexical choice, lexical cohesion, and sentence structure planning are lacking altogether. We intend to investigate these issues in future work. In the remainder of this section we describe the various knowledge resources of the planner.

2.1 Text Type Hierarchy

It has long been observed that certain types of linguistic phenomena (e.g., the rhetorical structure, lexical types, grammatical features) closely reflect the genre of the text (e.g., scientific papers, financial reports). A text generation system that contains a rich set of expressive possibilities requires some representation of genres or text types in order to constrain its options, since no other resource will provide the necessary information, and the system will be unable to choose between alternative formulations.

Several text typologies have been proposed by linguists. To mention only a few: Biber (1989) identified eight basic types of texts based on statistically derived grammatical and lexical commonalities. The Washington School proposed a detailed classification of different genres of written scientific and technical English (Trimble 85), additionally pointing out typical relationships within and between rhetorical/textual units. de Beaugrande (1980) proposed a general classification of text types, also arguing that text types determine the types of discourse structure relations used.

Given its generality, we decided to base our text planner's hierarchy of text types on that of De Beaugrande, with extensions as needed to handle the text types we are addressing. The hierarchy (partially shown in Fig. 1) is represented as a property-inheritance network in the knowledge representation system Loom (MacGregor 88). Each text type in this hierarchy has associated with it the constraints it imposes on other resources, such as which communicative goals it entails, which discourse relations it favors, any appropriate grammatical constraints, etc. As a result, once a type has been established for the text to be generated, the selection of other parameters used during the generation process can be constrained appropriately (for instance, interpersonal discourse relations almost never appear in objective scientific reports, while love letters tend to contain mainly those relations). Thus our planner's predefined text types help pre-select or de-activate certain options in the generation process.

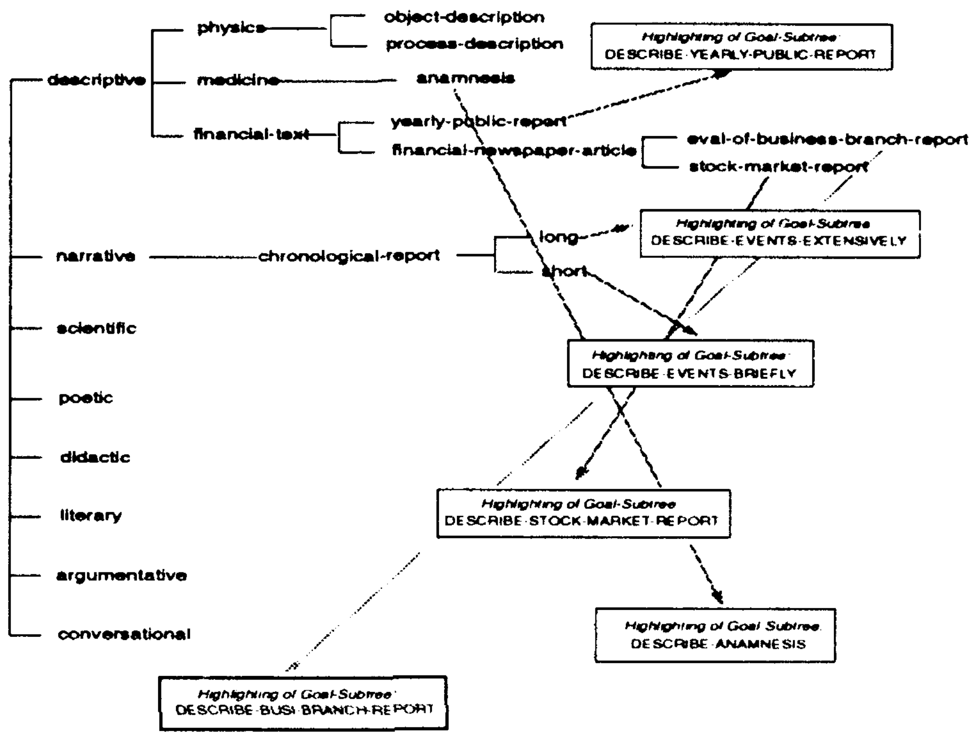

Fig. 1. A part of the Text Type Hierarchy.

2.2 Communicative Goal Hierarchy

Communicative goals have been used in many generation systems to describe the discourse purpose(s) of the speaker. Our planner contains a rudimentary taxonomization of communicative goals, starting at the topmost level with some very general goals, such as INFORM, DESCRIBE, REQUEST, and ORDER, which are eventually refined into specific goals to describe specific types of information for specific contexts (see Fig. 2). Our taxonomy, which is implemented as a property-inheritance network, resembles the one being derived from speech acts by Allen and his colleagues (e.g., Allen 91).

Planning for a communicative goal results in a discourse segment (a subtree of the discourse structure for the generated text). Each communicative goal contains one or more realization operators --- instructions for the planner to perform specific actions (see Section 3). We call our planner's lowest clause-level goals *planner primitive speech acts*; these primitive speech acts form the leaves of the discourse structure tree. During the planning process, they signal that the next step is grammatical realization.

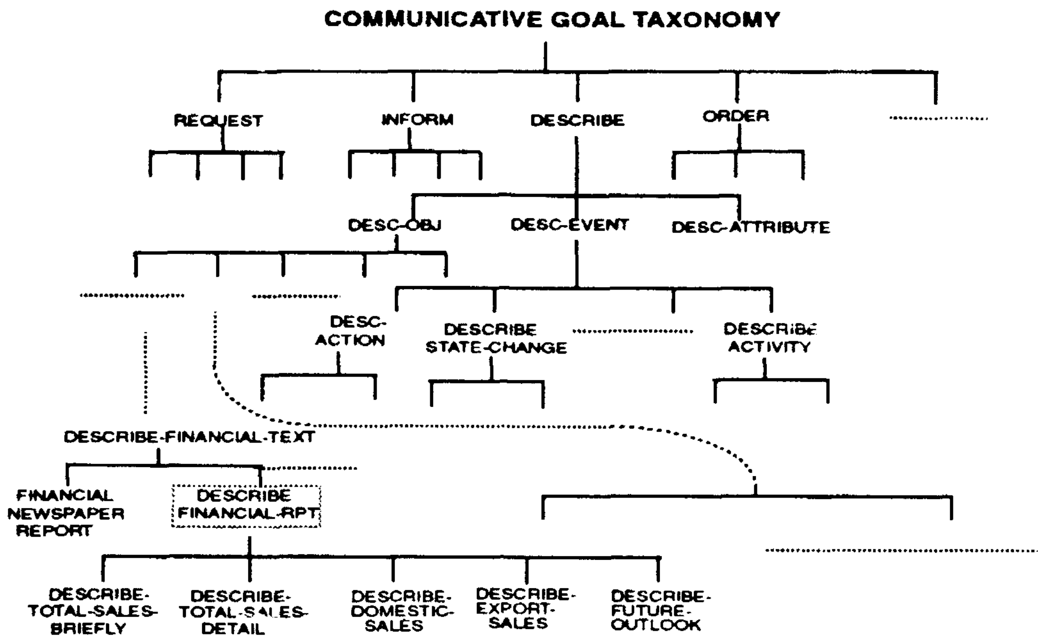

Fig. 2. A part of the Communicative Goal Hierarchy.

2.3 Schemas

In many circumstances, texts exhibit a stereotypical structure. In text planning systems, such structure is usually represented in schemas, which specify the topics of discussion that appear in the text as well as their ordering (e.g., McKeown 85). The stages of structural stereotypes can be defined at the clausal level (indicating the type of process of each sentence to be included and its position), but can equally well be defined at a more general level (indicating the sequence of general topics to be included). Linguists have proposed several schema-like approaches to model such structure: e.g., macrostructures (Van Dijk and Kintsch 83), holistic structures (Mann and Thompson 88), and the Generic Structure Potential (Halliday and Hasan 85). Recognizing the utility of such structures, we include them in our planner. We represent them as property-inheritance networks.[3]

A schema can be composed of several communicative goals: As an example, a

[3] We believe that, in spite of the frozen nature of schemas that capture frequently occurring patterns of text structure in specific situations, there still exist rhetorical relationships among the different parts of each schema. Given sufficient knowledge, a system should be able to plan out the same text without using a schema. However,

schema to generate financial reports could contain the following communicative goals in the dictated order (see Fig. 2): (1) describe-total-sales-briefly (heading); (2) describe-total-sales-detail; (3) describe-domestic-sales; (4) describe-export-sales and (5) describe-future-outlook. We show in Section 4 how this schema is used in our planner to generate a particular text.

Just as the previous two resources co-constrain the other resources (*e.g.*, the choice of text type can influence the selection of a schema), the instantiation of a schema can highlight or suppress different discourse relations, or the various stages of a schema can favor particular theme development patterns.

2.4 Discourse Structure Relations

Many linguists and computational linguists have studied the relationships that hold between sentences or segments of text, identifying relations that they claim need to hold in order for a text to be coherent; e.g., (Grimes 75, Mann 84, Hobbs 78, Mann and Thompson 88, Sanders *et al.* 91, Redeker 90). These relations can be used in a generation system in order to guide the selection and organization of the information to be included when other structuring guidance is lacking, such as when a schema stage calls for more material than can fit into a single clause. The necessity and use of discourse structure relations in text planners to ensure coherence has been amply discussed, as in (Hovy 88, Moore and Paris 89, Cawsey 90, Maybury 90).

Our text planner contains three networks of discourse relations, implemented as systemic networks. As a basis for the networks, we drew on several main sources: the relations defined in Rhetorical Structure Theory (Mann and Thompson 88), which were extended in Hovy's taxonomization of a collection of the relations proposed by over thirty researchers from various fields, later reorganized with Maier; see (Hovy 90, Maier and Hovy 91), and Martin's taxonomization of the conjunctive relations (Martin 92). We divided the relations into three major portions, according to the three major functions of language according to systemic linguistics (Halliday 85): semantic/ideational, interpersonal, and presentational/textual. Portions of the networks appear in Fig. 3. When organizing material, the planner is free in the general case to establish several discourse relations (typically, one for each of the major functions) between the existing discourse structure and the new piece of material; as shown in the networks, the selection of ideational, interpersonal, and textual relations is not exclusive.

As with the other resources, the discourse relation networks co-constrain the other knowledge resources, by, for example, preselecting theme patterns, posting communicative goals, or specifying aspects of grammatical realization.

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lacking a complete specification of all the resources required in generation, a planner can use schemas as a useful source of 'compiled knowledge' and so avoid the need to re-derive structures over and over again.

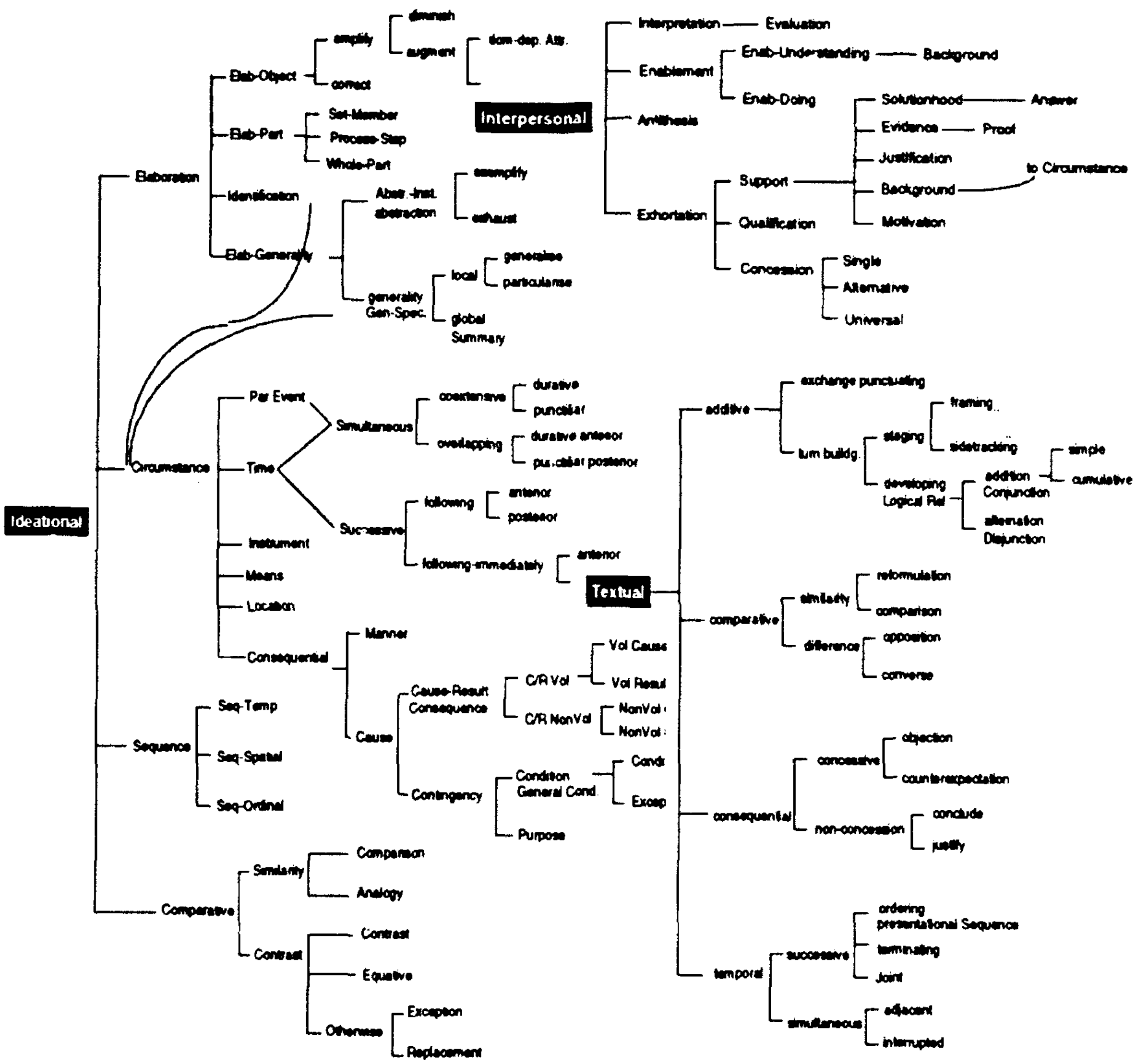

Fig. 3. Discourse structure relation networks.

2.5 Theme Development Information

Careful linguistic and computational studies have shown the need for a resource describing the potential theme developments and shifts of focus, in order to signal the introduction of a new topic of discussion and to provide its thematic relationship to previous topics (e.g., Halliday 85, Quirk *et al.* 72). Except for efforts such as Sidner (1983) and McCoy and Cheng (1988), these concerns have not been the subject of much computational work in text generation; they have generally taken the form of focus shift rules (McKeown 85, McCoy and Cheng 88, Hovy and McCoy 89). Unfortunately, these rules have usually been implemented procedurally and the complexity of the issues underlying them have not been fully studied. In the new text planner, we represent the potentialities of theme development declaratively in a systemic network (see Fig. 4).

Although the study of theme has traditionally been restricted to the sentence level, it also plays a role at the clause-complex and discourse levels. This should be taken into consideration by a text generation system. Given a text to be generated, the system must establish how theme development may proceed and how themes are to be marked in each clause. The following three concerns arise:

- the type of theme to select: following Halliday (1985), there can be three different and simultaneous themes in each clause: the ideational (or topical; expressing processes, participants, or circumstances), the interpersonal (expressing modal meanings such as probability, usuality, or opinion), and the textual (such as expressed by the continuatives "yes,", "well,", "oh,", and similar conjunctions). The first type is semantically required.
- the theme progression pattern involved: the new theme can be the same as the theme of the previous clause; it may be part of the rheme of the previous clause; or it may be an element of what is called the "hypertheme," or general discourse segment topic (Danes 74); Note that this is similar to the focus shift rules of Sidner and McKeown.
- the linguistic degree of markedness of the theme: realization depends on the type of clause.

The motivations behind each choice follow pragmatic principles of information processing, including:

- *the topic-comment constraint* (Werth 84, Giora 88), also known as the *graded informativeness requirement*: a message is maximally effective if information which is presumed or given in the context is presented before information which is new;
- *the processibility principle* (Leech 83): a text should be constructed so that it is easy to process in real time, by placing the focus tone group at the end of the clause (the *maxim of end-focus*) and the "heavy" constituents in final position (the *maxim of end-weight*);
- *discourse relation requirements* (Mann and Thompson 88): some discourse relations have a canonical (unmarked) order of surface realization.

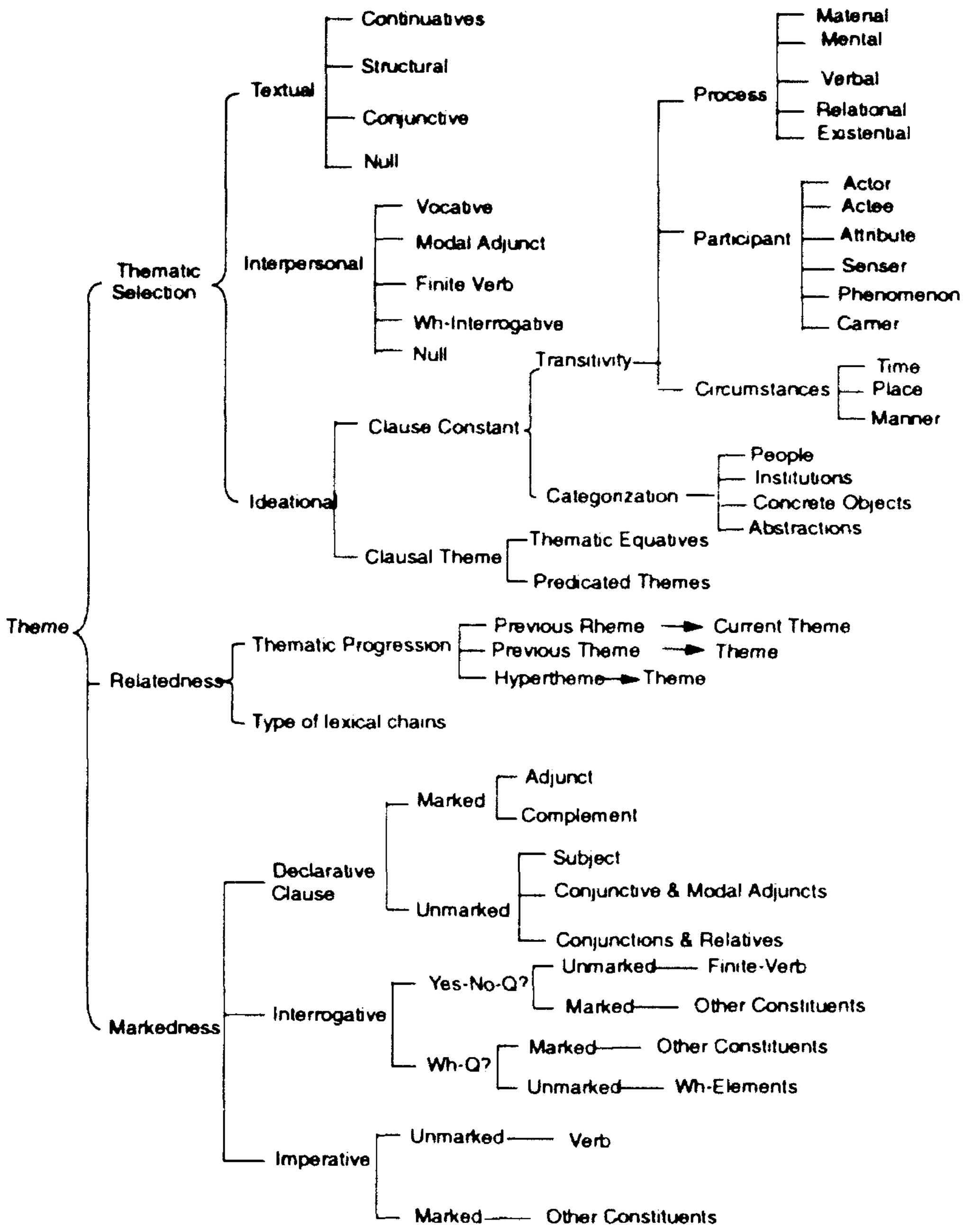

Fig. 4. A portion of the theme network.

3 The Planning Process

Planning with the networks proceeds analogously to the generation of single sentences with Penman (Penman 88, Mann 83, Mann and Matthiessen 85): in both cases, the traversal mechanism proceeds through the network, causing traversal choices to be made at nodes (systems), and building a tree-like structure as a result. We implemented the networks in Penman's internal notation so as to be able to reuse some of its traversal code.

Associated with each node in the networks is an inquiry function which queries the environment in order to determine which branch to follow, and a set of realization operators that instruct the planner what to do next.

The planning operation is very simple. After an initial setup phase, the system simply executes a basic planning cycle over and over again until planning is complete. In the setup phase, the user activates the planner with a communicative goal, as described in Section 2.2, which causes the selection of a desired text type, and is then posted on the goal stack and simultaneously on the Discourse Structure Tree. Then the basic planning cycle begins. Essentially, this cycle proceeds as follows: First, the planner checks whether there is a realization on the agenda. If so, it performs the realization by applying its action to its parameters. If there are no realizations left, the planner checks whether there is a discourse goal on the goal-stack. If there is, the planner finds the realizations associated with the goal and loads them onto the agenda; if no discourse goals remain, the planning is done.

Clearly, the action of the system lies in the realizations. Each realization is an instruction to be performed. At present, the system uses the following realizations:

1. (ACTIVATE-SCHEMA <schema-name>): Find the schema and load its realizations onto the agenda.
2. (ADD-TO-D-STRUC <goal> <concept> <parentpos>): Add the given communicative goal into the discourse structure tree at the given position.
3. (CHANGE-HYPERTHEME <chain-of-roles>): Change the topic under discussion to the filler of the given chain of roles, starting from the current topic.
4. (HIGHLIGHT-COMM-GOALS <goals>): Highlight the given goals so that only they will be considered for future planning.
5. (HIGHLIGHT-RELATION <relations>): Start traversal of the discourse relations network(s) at the given relations, using the current topic of discussion.
6. (BLOCK-RELATION <relations>): Mark the given discourse structure relations so that they cannot be traversed for the remainder of the current sentence.
7. (PREFER-THEME <concept-role>): Add instructions for the realization component that the given role of the topic under discussion should be thematized in the clause.
8. (SET-MACROTHEME <concept>): Change the overall topic of discussion.

9. (SET-UP-DISCOURSE-GOAL <goal>): Activate the given goal: load it onto the goal stack and into the discourse structure tree at the current growth point and add its realizations to the agenda.
10. (TRAV-ONE-NETWORK-NODE <node-name>): Locate the given node in the knowledge resource networks, apply its inquiry function, record the result (the inquiry choice), and load the realizations associated with the result onto the agenda.

4 An Example of the Planner in Action

In this section we provide a brief trace in order to show how the various linguistic resources interact to guide the construction of the discourse structure. As example we take a fragment of a text from a bank's annual report:

> (1) Declines in Total Sales of the Swiss Cheese Union
> (2) In the business year 1986/87 (ending July 31), the 40 cheese trading firms associated in the Swiss Cheese Union sold 79,035 tons of cheese altogether, (3) equal to a 2.6% decline. (4) Domestic sales of table cheeses enjoyed a relatively positive trend, (5) with Swiss households buying 22,100 tons of their preferred cheeses, (6) a gain of 3.9% from one year earlier.

We represented the semantic information in this text in the Loom knowledge representation system.

Given the communicative goal GENERATE-YEARLY-PUBLIC-REPORT and the topic of discussion CHEESE-UNION-SALES-86, the schema mentioned in Section 2.3 is activated, and the planner goes through the stages indicated in the schema. Let us assume now that the first two clauses -- the headline and the first clause -- have already been generated. The state of the discourse structure appears in Fig. 5.

In generating (2), the goal DESCRIBE-TOTAL-SALES-DETAIL is popped off the goal stack, and its definition in the goal hierarchy is checked. This new information is now incorporated in the discourse structure, and the realization statements for the goal are loaded onto the agenda, including the one to highlight the discourse structure relation interpretation.

In the next cycle, the planner checks the agenda and finds the just-loaded realization. It performs the realization by highlighting interpretation in the interpersonal relations network, which causes the planner to check whether any topic material with that relation to the current topic of discussion can be brought into the discourse. This check is performed by an inquiry function that accesses the planner environment with a question that can be paraphrased as:

> **Interpretation-Q-Code:**
> "Was a numerical value mentioned in the last proposition and can it be expressed in relation to other values?"

From the information about the topic (as contained in the knowledge representation system), a possible candidate for such a relation is the value of the role weight-ascription. The inquiry code retrieves a role and a value which

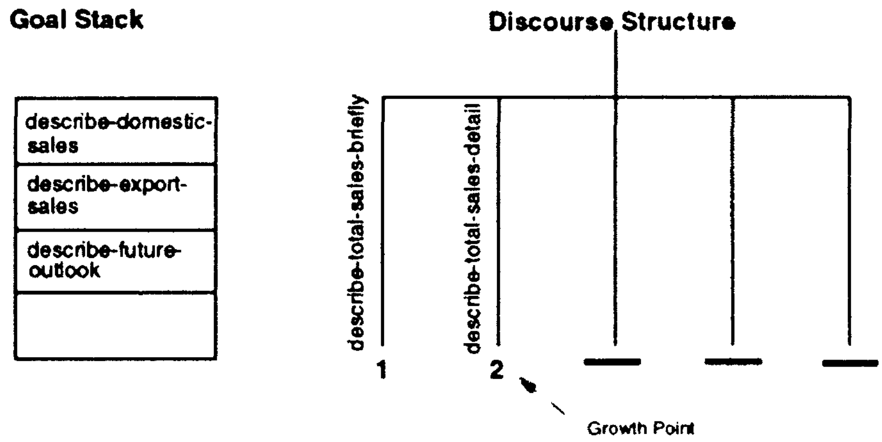

Fig. 5. Snapshot of the text planner state.

fulfills the above condition: the role `weight-change-relative` represents the weight ascription relative to that of the preceding year. The relevant segment of the domain model appears in Fig. 6.

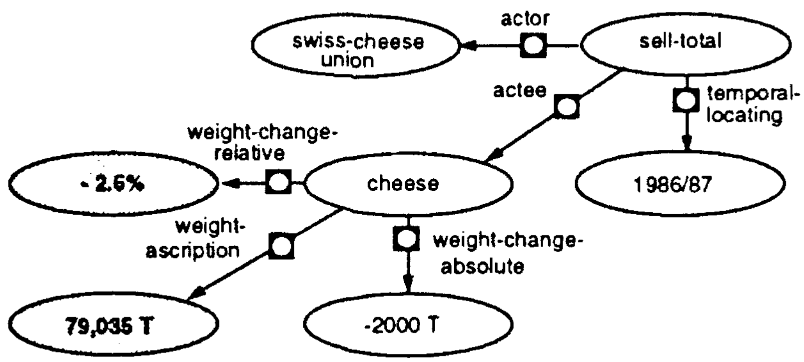

Fig. 6. Fragment of the Domain Model.

The successful finding of this material signals the applicability of the relation `interpretation`. The planner then activates the realization statements associated with this relation, in this case:

1. **knowledge selection:** Each relation contains specifications of the material it relates. The realization associated with `interpretation` selects both the absolute and the relative ascriptions for the weight, and calls for incorporating this new information.
2. **discourse structure growth:** This realization calls for the addition of the `interpretation` relation at the current growth point in the discourse structure tree of Fig. 5.
3. **theme determination:** This realization calls for traversal of the theme network in order to determine the thematization pattern of the new clause or clauses.
4. **operations on relations:** To prevent the repetitive use of the interpretation relation, which would lead to a monotonous text, this realization calls for `interpretation` to be blocked for further use until the end of the next sentence.

The planner loads these four realizations onto the agenda and thereby completes its cycle.

In the next cycle, the planner runs the knowledge selection realization listed above and selects the new material. In the following cycle, it adds the interpretation relation to the discourse structure tree. This relation indicates that clause (3) is related to clause (2) by the rhetorical relation `interpretation`. The resulting form of the discourse structure after these realizations appears in Fig. 7. In the following cycles, the remaining realization statements are executed.

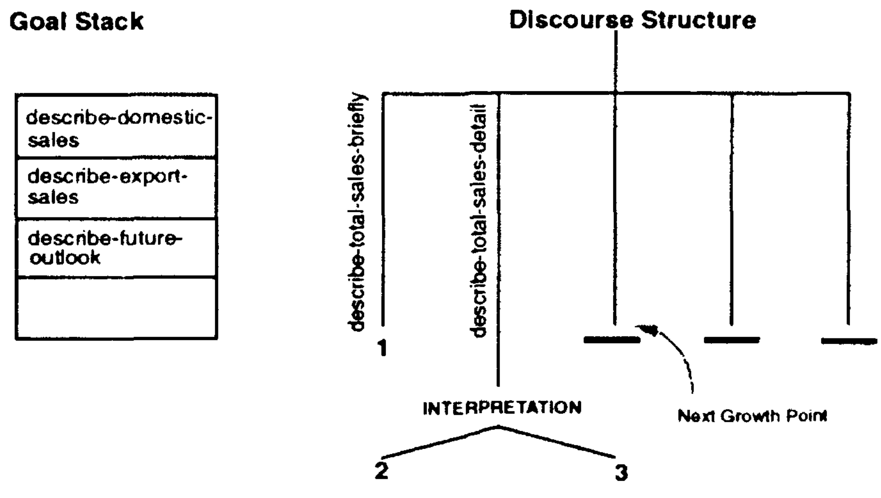

Fig. 7. Discourse structure after the new relation has been planned.

We cannot describe the rest of the planning in detail here. In essence, the planning cycle keeps repeating, first handling all the realizations on the agenda and then all the goals on the goal stack, until no more remain.

5 Conclusion

We have presented in this paper a new text planner currently being developed jointly at USC/ISI and GMD-IPSI. It is based on the idea that the linguistic resources needed to generate coherent text (as well as their interrelationships) should be represented explicitly, separately, and distinct from the procedural knowledge required for text planning.

We do not claim to have identified all the knowledge sources required to produce coherent discourse. We are only starting to study the issues of lexical choice and lexical cohesion in depth (Wanner and Maier 91), and the planning of noun groups (and referring expressions in general), the problem of sentence delimitation are all unaddressed in our planner. We do, however, believe that the architecture of our planner lends itself well to the incorporation of additional knowledge resources when they become available. The representational power of systemic networks --- interlocking options that capture the potentialities of expression --- and the clear and simple planning cycle offer, we hope, sufficient scaffolding for the needs of text planning of the future.

Other issues of course remain to be addressed as well. For example, will we be able to keep the complexity of the procedural aspect of the system to a minimum? As the inquiry operators are implemented procedurally, we clearly need to limit how much can be done in these operators, or, at least, we need to apply clear constraints to be used when writing these operators lest their complexity becomes such that they are hard to understand and modify. We also need to study how the architecture addresses some of the concerns raised by some researchers regarding top-down planners (e.g., Suthers (1991) and Mooney, Carberry and McCoy (1990)) . It is too early to discuss these issues. We will address them once the system has been more fully implemented and used to generate a greater variety of texts.

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